AD-A251 867

Technical Report 949

(1)

The Effects of Differences Between Practice and Test Criteria on Transfer and Retention of a Simulated Tank Gunnery Task

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April 1992

United States Army Research Institute for the Behavioral and Social Sciences

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REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
1992, April

3. REPORT TYPE AND DATES COVERED
Final Jan 91 - Oct 91

4. TITLE AND SUBTITLE
The Effects of Differences Between Practice and Test Criteria on Transfer and Retention of a Simulated Tank Gunnery Task

5. FUNDING NUMBERS
63007A
795
3104
H1

6. AUTHOR(S)
Lampton, Donald R. (ARI); Bliss, James P., and Meert, Marie (University of Central Florida)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute
Orlando Field Unit
12350 Research Parkway
Orlando, FL 32826-3276

8. PERFORMING ORGANIZATION REPORT NUMBER
ARI Technical Report 949

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Research Institute for the Behavioral and Social Sciences
ATTN: PERI-I
5001 Eisenhower Avenue
Alexandria, VA 22333-5600

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
--

11. SUPPLEMENTARY NOTES
--

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release;
distribution is unlimited.

12b. DISTRIBUTION CODE
--

13. ABSTRACT *(Maximum 200 words)*

This report evaluates manipulation of the difficulty of practice criteria, relative to test criteria, as a method of improving performance on track-and-shoot tasks. The experimental task required manual tracking with the Videodisc Gunnery Simulator, a tank-gunnery training device. Each of three groups of 15 male undergraduates practiced under one of three conditions in which the accuracy criterion was easier than, more difficult than, or the same as the transfer and retention test criterion. Each accuracy criterion was defined as the percentage of the target area scored as a kill when hit. Dependent variables were target kills, aiming error, and time to fire. Results suggested a speed/accuracy trade-off: Compared with a control group that practiced and was tested with the same criterion, practice with an accuracy criterion more difficult than the test criterion yielded greater hit percentages, but slower firing times. This trend, although not statistically significant, held for transfer and retention test scores. Practice with an easier criterion did not result in systematic differences from the performance of the control group.

14. SUBJECT TERMS
Instructional strategies
Armor training
Retention
Training strategies
Transfer of training
VIGS

15. NUMBER OF PAGES
49

16. PRICE CODE
—

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Unlimited

NSN 7540-01-280-5500

Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. Z39-18
298-102

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Department of the Army

April 1992

Army Project Number
2Q263007A795

Training Simulation

FOREWORD

Because computer-based simulations are safer and usually less expensive than training with weapons systems, they will play an increasingly important role in military training.

The U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), in coordination with the U.S. Army Project Manager for Training Devices (PM TRADE) and the University of Central Florida's Institute for Simulation and Training (IST), recently began a research program to examine applications of learning and training principles to the design and use of training devices. The research program was established to identify conditions under which alternatives to traditional methods for teaching psychomotor skills such as tank gunnery can yield increased trainee proficiency, decreased training costs, or both.

The research reported here was performed by the Orlando Field Unit at PM TRADE as part of Task 3104, "Advanced Technology for the Design of Training Devices." The research program addresses the cost effectiveness of training devices as a function of the fidelity, instructional features, and instructional strategies. PM TRADE sponsored the research, which was accomplished under a Memorandum of Agreement with ARI dated 24 October 1991. The results of this research have been briefed to PM TRADE's Project Manager, Close Combat Training Systems; PM TRADE's Project Manager, Videodisc Gunnery Simulator (VIGS); PM TRADE's Research and Engineering Management Branch; and IST. Information about the conduct and results of the experiment was also provided to the manufacturer of VIGS.

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THE EFFECTS OF DIFFERENCES BETWEEN PRACTICE AND TEST CRITERIA ON TRANSFER AND RETENTION OF A SIMULATED TANK GUNNERY TASK

EXECUTIVE SUMMARY

Requirement:

Most training devices incorporate an instructional subsystem that controls learning and retention of the tasks and skills the device is designed to train. Instructional subsystems control such aspects of the training as difficulty of training and test criteria, training sequencing, and feedback content and amount. The instructional subsystem should be supported by research findings that document the efficiency of the approach to produce desired training outcomes. This research compares the effects of practice using performance criteria that were easier than, more difficult than, or the same as the test and retention criterion.

Procedure:

Each member of three groups of 15 randomly assigned male undergraduates from the University of Central Florida received three blocks of 18 practice trials with a tank-gunnery training device, the Videodisc Gunnery Simulator (VIGS). VIGS has targets whose kill zone, the percentage of the target-silhouette area that is scored as a kill when hit, can be varied. Each of the three groups practiced with the kill zone at one of three settings: 50%, 100%, or 150% of the target-silhouette area. Subjects in each groups were tested immediately after training with the kill zone set at 100% and were tested again after a 10-week retention interval. Dependent variables were target kills, aiming error, and time to fire.

Findings:

The results of this experiment suggest a speed/accuracy trade-off: Practice with an accuracy criterion more difficult than the test criterion yielded greater kill percentages and slower firing times than did practice and testing with the same criterion. This trend, although not statistically significant, held for transfer-test scores and retention-test scores. The effects of practicing with easier criteria than the test criteria were not reliably different from the effects of practicing with accuracy criteria that were the same as the test criteria.

Problems with the test scenarios and the small number of subjects available for retention testing contributed to the unreliability of differences among the groups' scores.

Utilization of Findings:

Training system developers and managers should consider the results of this and related experiments in deciding whether to use reduced kill zones and other training methods that may increase the accuracy of trainee performance at the expense of speed. The aspects of tank-gunnery training doctrine that pertain to the relative importance of speed and accuracy--the emphasis on first-round hits, for example--should be reexamined in light of literature about speed/accuracy trade-offs. Additional research should aim to establish exact, quantified, and generalizable speed/accuracy trade-offs for various firing conditions in simulators and in weapons systems.

THE EFFECTS OF DIFFERENCES BETWEEN PRACTICE AND TEST CRITERIA ON TRANSFER AND RETENTION OF A SIMULATED TANK GUNNERY TASK

CONTENTS

	Page
INTRODUCTION	1
Presumed Benefits of Differences Between Practice Criteria and Test Criteria	2
Asymmetrical Transfer Research	4
Adaptive Training Research	6
Dimensions of Training Effectiveness	7
Purpose, Rationale, and Hypotheses	8
METHOD	9
Subjects	9
Materials	10
Design	10
Procedure	13
RESULTS	14
Practice	16
Transfer and Retention	21
DISCUSSION	23
Practice	23
Transfer and Retention	24
REFERENCES	27
APPENDIX A. DESCRIPTION OF VIGS	A-1
B DISCUSSION OF PROBLEMS WITH VIGS SCENARIOS	B-1
C. HUMAN SUBJECTS CONSENT FORM AND VOLUNTEER AGREEMENT	C-1
D. SUBJECT BACKGROUND INFORMATION	D-1
E. INSTRUCTIONS TO SUBJECTS	E-1

CONTENTS (Continued)

Page

LIST OF TABLES

Table 1. VIGS disks used for each trial block 12

2. Means/standard deviations for time to fire (TF), kill percentage (K%), and aiming power (AE) per group by trial block 15

3. MANOVA summary tables 19

4. ANOVA summary table for kill percentage by practice blocks 20

5. ANOVA summary table for time to fire by practice blocks 20

6. ANOVA summary table for aiming error by practice blocks 21

7. ANOVAs summary table across groups for kill percentage, time to fire, and aiming error by test block 22

8. ANOVAs summary table across groups for kill percentage, time to fire, and aiming error for retention form 1 22

9. ANOVAs summary table across groups for kill percentage, time to fire, and aiming error for retention form 2 22

LIST OF FIGURES

Figure 1. Mean target kills (%) as functions of blocks of practice, transfer, and retention trials for each of three kill zone percentages 16

2. Mean time to fire as functions of blocks of practice, transfer, and retention trials for each of three kill zone percentages 17

CONTENTS (Continued)

Page

Figure 3. Mean aiming error as functions of blocks of practice, transfer, and retention trials for each of three kill zone percentages 18

THE EFFECTS OF DIFFERENCES BETWEEN PRACTICE AND TEST CRITERIA ON TRANSFER AND RETENTION OF A SIMULATED TANK GUNNERY TASK

Introduction

Most training devices incorporate instructional subsystems that consist of instructional features such as freeze, replay, and performance measurement as well as an instructional strategy that includes how these features are to be used and what course the training is to take. The domain of instructional features was outlined by Hughes (1979). Sticha, Singer, Blacksten, Morrison, and Cross (1990) developed a prototype expert system that incorporates rules for the selection of certain instructional features. Other than the work by Sticha et al. (1990), there is little guidance on the conditions under which to use various instructional features. **Perhaps more important,** there is little guidance about how to develop an instructional strategy using the instructional features. Such guidance is necessary because one can imagine conditions under which different instructional strategies could facilitate, degrade, or have no effect on learning and/or skill retention.

An instructional feature of three of the U.S. Army's tank-gunnery training devices, TOPGUN, the Videodisc Gunnery Simulator (VIGS), and the Conduct of Fire Trainer (COFT), is the capability to vary the target kill zone. The kill zone is the percentage of the target-silhouette area that is scored a kill when hit. Kill zones can be set to be the same size as, or smaller than, the target silhouette. (The Videodisc Gunnery Simulator (VIGS) allows the kill zone size to be larger than the target **silhouette.** Scoring algorithms award points for rounds striking within the programmed kill zone. One purpose of a programmable kill zone is to teach the concept that, under most conditions, a shot that hits the center of the target is superior to shots that hit elsewhere.

The programmable kill zone can also be manipulated within an instructional strategy. The evaluator/instructor can aid or challenge the student gunner by increasing or decreasing the area in which rounds must hit to constitute a "kill" (M1/M1A1, Tank Videodisc Gunnery Simulator (VIGS), Device 17-142, Instructor's Utilization Handbook for Simulation Equipment, 1988). The implication seems to be that instructors should increase the size of kill zones to aid students who are having difficulty hitting targets and should decrease kill zones to challenge students who are hitting targets regularly.

The availability of programmable kill zones relates to an unresolved behavioral science issue of long standing; namely, under what conditions may learning be facilitated (or degraded) by practice in which criteria are more difficult than, the same

as, or less difficult than the criteria used in tests of transfer and retention? Research and thinking aimed at resolving that issue include four areas of inquiry:

1. Presumed benefits of differences between practice criteria and test criteria.

2. Asymmetrical transfer research.

3. Adaptive training research.

4. Dimensions of training effectiveness.

Presumed benefits of differences between practice criteria and test criteria. A considerable amount of research has been conducted to examine the proposition that superior transfer of training may be obtained by varying practice criteria from transfer criteria **(Mane et al. 1989)**. Lintern (1991) noted that advantages for both practice with easier criteria and for practice with more difficult criteria have been hypothesized.

Wightman and Lintern (1985) reviewed strategies for part-task training of tracking and control tasks. They recounted assumed advantages for having training task criteria differ from transfer task criteria. An argument in favor of training with an easier criterion is that for training very difficult tasks, initial practice with a high level of difficulty may preclude meaningful practice. Therefore, initial training with an easy version of the task would be desirable. An argument for training with a more difficult criterion is that practice with a more difficult version of the task forces trainees to extend themselves. This may lead to faster learning of skills needed for performance of the transfer task. Also, practice with criteria more difficult than transfer criteria may establish resistance to forgetting and stress.

Wightman and Lintern pointed out that using a practice task that is less difficult than the transfer task is common in educational and instructional environments. However, they noted that for training tracking skills for manual control there is little empirical evidence to indicate that training with an easier criterion is more effective then training with the task criterion. Nevertheless, they proposed that there is some indication that training for a highly difficult transfer task may best be accomplished by training with a moderately difficult version of the task. They recommended further research in this area.

Wightman and Lintern described an experiment **that found** superior transfer for training with a more difficult version of the transfer task than training with the transfer task. In that experiment, Williges and Baron (1973) employed a response surface

methodology to measure transfer of a tracking task as a function of three variables: number of training trials, time between training trials, and tracking speed of the training task. The measure of transfer was number of trials on the transfer task to reach a time-on-target criterion. Practice with a tracking speed faster than the speed used for the transfer tracking task was found to produce superior transfer than practice with the tracking speed of the transfer task.

Ecklund (1975) cited three experiments that indicated that training with practice targets that were smaller, that is more difficult, than the transfer test targets produced transfer superior to training with targets of the size of the test targets. The experiments cited by Ecklund were conducted by Mace (1931) and Day (1954), both employing a pencil spearing task, and by Igbanugo (1972) employing a basketball passing task. Ecklund also cited an experiment, employing throwing tasks, by Scannel (1964) that involved similar training manipulations but showed no differences in training effectiveness. Ecklund stated that research in this area was inconclusive. He noted that reducing the size of basketball rims was a current training practice. The practice was based on the assumption that training with a smaller rim would produce better shooting accuracy when transferred to a regulation-size rim than training with a regulation-size rim.

Abel (1986) conducted a series of experiments to examine practice effects on the BATTLESIGHT tank gunnery trainer. (BATTLESIGHT was a prototype for the TOPGUN gunnery trainer.) One of the experiments included a manipulation to investigate practice with a reduced kill zone.

Abel's experiment also included a manipulation to look at aspects of game format, for example, the distribution of ammunition and player "lives". There was no significant effect for game format nor was there a significant interaction of game format and kill zone size. However, the variations in game format, although completely crossed with kill zone size variation, complicate the interpretation of the effects of kill zone size. For example, the game format manipulations allowed, and resulted in, considerable variation across subjects of the number of rounds of ammunition fired.

Abel found that subjects firing at targets with reduced kill zones, in contrast to subjects firing at targets with 100% kill zones, had significantly lower percent hits and percent first round hits. (A round was scored as a "hit" if it impacted within the defined kill zone. Rounds that impacted within the target silhouette, but outside the defined kill zone, were treated by the BATTLESIGHT scoring system as misses.) Kill zone setting did not result in significant differences in average time to fire. For both levels of kill zone size, time to fire decreased

as a function of practice, however, hit (kill) rate did not significantly improve as a function of amount of practice.

Abel interpreted the improvement in firing time and the lack of improvement in hit rate as an indication of subjects' emphasis on speed over accuracy. Abel presented the argument that many aspects of video games, especially the scoring algorithms, encourage emphasis on speed rather than accuracy of performance.

Abel employed hit rate as a measure of firing accuracy. Stating that the subjects in the reduced kill zone group were less accurate than the subjects in the standard kill zone group raises questions of terminology. The difference in group scores was probably a function of an application of different standards, not a function of differences in aiming skill. Measures of aiming error deviation, in elevation and azimuth, were not available. The group of subjects that practiced with the reduced kill zone was not transferred to firing with a standard kill zone.

The experiment described in this report employed the programmable kill zone size of the VIGS trainer to examine the instructional strategy of varying the difficulty of practice criteria in relation to test criteria. This research differs from that conducted by Abel in that the focus of the present experiment is on transfer and retention, not only on differences in performance during practice itself.

Asymmetrical transfer research. In the asymmetrical transfer paradigm one group practices with an easy version of a task and then the group is tested with a difficult version of the task. The amount of transfer is compared with that of a group for which initial practice is with the difficult version of the task and transfer is measured for performance of the easy version of the task. Day (1956) reviewed several experiments that demonstrated asymmetrical transfer. Some of these experiments demonstrated that easy-to-difficult sequencing of practice and transfer tasks results in higher transfer than a difficult-to-easy sequence. Other experiments have found better transfer with the difficult-to-easy sequence. Day pointed out that these findings of asymmetrical transfer have important implications for practical issues in training as well as for transfer theory.

Day proposed that a skilled task possesses three basic features: a stimulus complex (display), operator control devices, and the linkage between display and controls. The difficulty of a task may vary as a function of changes in one or more of these features. According to Day, previous research indicated that transfer was greater for easy-to-difficult when stimulus alone was varied. Transfer was greater for difficult-to-easy when task difficulty was varied with respect to response variables, for example, rate of responding. However, Holding (1965) noted that

manipulations of task difficulty often involve changes in both the stimulus and response components of the task.

Day emphasized that many of these experiments were designed without control groups. That is there were no easy-to-easy or difficult-to-difficult comparison groups. He pointed out that such groups are important, for both practical and theoretical reasons, to allow conclusions about maximum transfer. He noted inconsistencies in this area of investigation in defining difficulty, scoring, and estimating extent of transfer. These inconsistencies hamper explanation of the differential findings.

Holding (1962) reviewed more than thirty studies concerned with the transfer of training between difficult and easy tasks. Although many of the studies demonstrated asymmetrical transfer, neither order of training, easy-to-difficult nor difficult-to-easy, was consistently superior. He pointed out that this inconsistency of superiority for one approach over the other occurred not only across kinds of tasks but could also be expected for different stages of learning for individual tasks. That is, with small amounts of practice, easy-to-difficult transfer may be superior but for transfer after larger amounts of practice difficult-to-easy transfer may be greater.

Holding (1965) proposed that the concept of inclusion may provide a partial explanation of the instances for which difficult-to-easy produces greater transfer than the reverse. Difficult-to-easy transfer is superior because the difficult task includes components of the easy task. He provided examples of inclusion: after practicing to shoot an apple no further practice is needed to hit a barn door, a telegraphic operator who can receive Morse code sent at twenty-four words a minute needs no additional training to receive code at a slower, easier, rate.

Holding (1962) suggested that instances of superiority of easy-to-difficult transfer conditions could be explained in terms of error size constancy. Initial practice with the easier task leads to smaller error size than practice with the difficult task. Holding proposed that there is a tendency to carry over the mean error size from the practice task to the transfer task. Holding (1965) restated this explanation of findings of superiority of easy-to-difficult transfer, using the term "performance standards". (Performance standards referred to the level of performance of the subject, not task criteria set by the experimenter.) High performance standards are established under the easy condition. Looser performance standards are established under the difficult condition. Under the transfer condition, subjects tend to maintain the standards established during practice. Holding noted that if the difficult condition were much more difficult than the easy condition then performance standards could not be maintained. For this situation superior

difficult-to-easy transfer would be observed as a function of inclusion.

Holding (1962) stated that the interaction between inclusion and error constancy is further complicated by the strategies adopted by subjects and by the emphasis on speed or accuracy demanded by the structure of the task. Holding maintained that there is an extremely complex interaction of factors that influence transfer between difficult and easy tasks. In addition, he emphasized that findings of asymmetrical transfer do not indicate that practice with an easier or more difficult version of the task is a better training approach than practice with the transfer task.

Holding (1962, 1965) described general problems with using the concept of task difficulty in predicting transfer of training. Holding (1962) pointed out that the terms "easy" and "difficult" are used in a relative sense within experiments. The condition designated as "difficult" in one experiment might actually be easier than the "easy" condition of another experiment. Reconciliation of conflicting results across experiments is hampered by the lack of a measure of absolute difficulty.

Holding (1965) noted that the term "difficult" is used to describe tasks that show high error scores or long learning curves. Many different task characteristics, such as speed or target size, contribute to task difficulty. Each of these characteristics may lead to different transfer effects. Holding argued that it may be more useful to concentrate on task characteristics, rather than task difficulty, in predicting transfer effects.

Adaptive training research. Kelley (1969) defined adaptive training as training in which the practice task is varied as a function of how well the trainee performs. With adaptive training the difficulty of the practice task is adjusted to the performance level of the trainee. Task difficulty is increased after successful trials and decreased after unsuccessful trials. To support adaptive training three features are required of training simulators. 1) The simulator must have a performance measurement system capable of continuously or repetitively measuring trainee performance. 2) A means of adjusting some characteristic, the adaptive variable, of the task is required. 3) An adaptive logic which automatically changes the adaptive variable as a function of performance is needed.

Adams (1987) pointed out that the adaptive training approach is based on the assumption that training on the transfer task itself is not necessarily the most efficient approach to training. In comparison to practice on the criterion task itself, the adaptive sequence of practice presumably leads to

faster learning, or a higher level of learning, of the criterion task. Adams stated that adaptive training is an intuitively attractive idea but has failed to prove effective for training tracking tasks.

More recently, Lintern (1991) noted that although early attempts to demonstrate an advantage for adaptive training were unsuccessful, recent attempts have been more encouraging. He cited research by Mane et al. (1989) that employed as the adaptive variable the speed of hostile forces in a video game. Practice with a reduced speed, half criterion speed, was superior to control training. However, practice with a more greatly reduced speed, one-quarter criterion, was not advantageous. He proposed that two competing processes may come into play when a task is simplified during adaptive training. Simplification of a task during practice may aid skill acquisition but may also distort the task, reducing positive transfer. To be effective an adaptive training manipulation must take advantage of the benefits of simplification while minimizing the disadvantages.

Dimensions of training effectiveness. Mane, Adams, and Donchin (1989) emphasized that transfer of training is a key criterion to evaluating the usefulness of a training program. Level of performance on the practice task is not necessarily predictive of the amount of transfer that will take place. Reducing the difficulty level of the practice task will produce better performance during practice but may result in less transfer to the target task.

Schmidt and Bjork (in preparation) argued that a comprehensive measure of the effectiveness of military training must not be based entirely on performance during training or on a short-term transfer test. Rather, measurement of training effectiveness must place emphasis on measures of retention. Retention is the critical factor for ensuring combat readiness during emergencies and for minimizing retraining time. They noted that generalization and capability to perform under stress should also be considered in evaluating the effectiveness of military training.

They contended that current training designs are often based on an erroneous assumption: variations in practice conditions that result in the highest level of performance during practice represent the best training approach. Schmidt and Bjork described three experimental manipulations of practice conditions that, relative to control conditions, led to slower acquisition or inferior performance during practice but better performance on tests of retention. The manipulations involved exercise sequence, feedback schedule, and task variation. These findings lead us to question the effectiveness of current training approaches and suggest alternatives that may lead to low-cost methods of improving simulator-based training. In addition, the

findings indicated that advantages of variations in practice conditions that lead to superior retention may go undetected by transfer tests conducted soon after practice.

The practice manipulations used in this experiment differ from those cited by Schmidt and Bjork. However, their argument that evaluations of the training effectiveness of practice manipulations should include measures of retention was one of the factors which led us to take a new look at an old issue: the optimal relation between practice criteria and (transfer) test criteria.

Purpose, Rationale, and Hypotheses. There are theoretical arguments, and some equivocal empirical evidence, that practice with criteria that differ from test criteria can produce training superior to training for which practice and test criteria are of equivalent difficulty. Arguments for practice with easier criteria and arguments for practice with more difficult criteria have been presented. Wells and Hagman (1989) pointed out that research to date had not provided practical guidelines for determining when one approach is to be preferred over the other.

The U.S. Army Research Institute, under sponsorship by the U.S. Army Project Manager for Training Devices, and in coordination with the University of Central Florida's Institute for Simulation and Training, has begun a research program to examine potential advantages of alternatives to traditional training methods. This report describes the first experiment conducted under that program. The purpose of this experiment was to evaluate manipulation of the difficulty level of practice criteria as a method of improving transfer and retention of a track-and-shoot task.

Two competing hypotheses were considered. The first was that practice with a more difficult criterion, the kill zone set to 50% of the size of the target silhouette, would lead to better transfer and retention than practice with the transfer (control) criterion itself, the kill zone set to 100% of the size of the target. We hypothesized that practice with the more difficult accuracy criterion would lead to better transfer scores when the accuracy criterion was relaxed. We assumed that practice with a smaller kill zone would demand greater aiming precision and lead to a more refined skill.

We speculated that practice with a stricter accuracy criterion could also lead to better retention performance, occurring in the following manner: Practice with a smaller kill zone encourages a tighter shot pattern around the target center of mass. During practice, the smaller kill zone results in a lower kill rate because the smaller kill zone constitutes a more difficult task. During the no-practice retention interval, aiming precision deteriorates, i.e. the shot pattern shows

greater dispersion, at an equal rate for both groups. During retention testing, for both groups more shots fall outside of the boundaries of the kill zones with which they practiced. For the control group shots falling outside of the practice kill zone are misses. However, for the difficult practice group some of the shots falling outside of the original kill zone setting are still within the (relatively) easier criterion used for the retention test. Therefore, on a retention test subjects initially trained with the stricter criterion would have a greater percentage of their shots hitting within the kill zone.

The second hypothesis was that practice with an easier criterion, i.e. the kill zone set to 150% of the size of the target, would lead to better transfer and retention. An argument for this prediction is that during practice with an easy criterion subjects establish high performance standards, i.e. a high kill rate, which they endeavor to maintain during transfer and retention testing. (This experiment did not evaluate the situation for which training with an easier criterion seems most appropriate: the need to train for a transfer task that is too difficult to allow for meaningful practice by naive subjects.)

The first hypothesis, that practice with a more difficult criterion may lead to better transfer and retention than practice with the transfer criterion, was our primary interest because we felt it represented a viable training strategy. In contrast, the easy practice condition employed in this experiment might be expected to lead to negative transfer because rounds were scored as kills even though they hit outside of the target silhouette. Although the easy practice condition was questionable as a practical training strategy we believed that the condition could help us interpret the effect of variations in practice difficulty and therefore we included the condition in the experiment.

The experimental design involved within-device transfer. Positive results would lead to consideration of further research investigating transfer to higher fidelity trainers, such as COFT, or to live fire performance. Because this was exploratory research we employed a relatively small sample size of 15 subjects per group.

Method

Subjects

Forty-five male undergraduates served as subjects. (Fourteen subjects returned for the retention test). Subjects were paid for their participation. All subjects reported normal color vision.

Materials

VIGS: (A detailed description of VIGS is presented in Appendix A.) The M1 Videodisc Gunnery Simulator (VIGS) is a tabletop part-task trainer for M1 tank gunnery. The VIGS trainer utilizes computer generated imagery (CGI) to present engagement scenarios to the trainee. The scenarios depict stationary and moving targets and realistic terrain. VIGS represents the controls for target tracking and engagement, and the switches for ammunition and sight selection, needed to practice tank gunnery.

Four different disks (videodisks) of scenarios are available for the M1 VIGS. Each VIGS scenario depicts a scene as viewed through the gunner's sight of an M1 tank. Each scene contains terrain, such as hills or flat stretches of sand. Most scenes also contain vegetation, such as grass and trees, and cultural objects, such as houses. CGI targets are superimposed upon the terrain representation. Target types are: tanks, helicopters, BMPs (Warsaw Pact infantry fighting vehicles), trucks, and troops. Some scenarios present single targets, some present two targets. Stationary and moving targets are presented and some scenarios represent movement by the firing vehicle.

From three of the VIGS disks we selected a subset of the total set of available scenarios (missions). Scenarios that required degraded mode gunnery or use of the COAX machine gun were excluded to avoid the additional train-up time that would have been required to prepare subjects for these kinds of scenarios. Also, multiple target scenarios were excluded to simplify the data analysis, that is, each scenario presented only one target.

Design

The VIGS capability to define the target kill zone as a percentage of the target silhouette was used to vary the criterion for accuracy required to score a kill. A kill zone designated as "100%" defined a rectangle just big enough to completely enclose the target silhouette. The internal simulation representation of a target was therefore not identical in size or shape of the visual representation of the target presented to the trainee. It should be noted that the kill zone was not visually observable by the subject. The visual characteristics of the targets were not altered by changing the kill zone. No representation of the kill zone was superimposed on the targets. The apparent size of each target was a direct function of the range to the target and the target type (tank, helicopter, BMP or truck) and, therefore, target size, and kill zone size, varied across exercises. That is, the absolute size of the kill zone of a target was a direct function of the target size and the kill zone setting. The speed at which the targets

moved was unaffected by the kill zone setting. The size, range, and movement speed of targets were constant across groups. The differences in the treatment of groups were: (1) the initial instructions given to the subject in regard to the size of the defined kill zone, and (2) the kill zone parameter used by the simulation to determine if a shot was scored as a kill.

Subjects were randomly assigned to groups. Each group received three blocks of practice engagements (trials) with eighteen engagements per block. One group (labelled KZ150%) practiced with the target kill zone set at 150% of the target silhouette; a second group (KZ100% or CONTROL) practiced with the target kill zone set at 100% of the target silhouette; a third group (KZ50%) practiced with the target kill zone set at 50% of the target silhouette. For the three practice blocks, each scenario was presented twice in each block in random order except for the restriction that the same scenario could not appear consecutively. Five sets of random orders of scenarios were used for the blocks of practice engagements. (Complete randomization of scenario order across subjects was precluded by the difficulty of the VIGS' procedure for selecting and storing the order of scenario presentation.)

Following practice, all groups were tested with a 100% kill zone using twenty engagements from either disk #2 or disk #3. The targets engaged during the test were similar to those encountered during practice, but were not exact duplicates. Subjects returned ten weeks after the test for a retention test, which required subjects to engage the set of 18 engagements from disk #1 and then 20 test targets from the same disk as they had used during the original test session. (Note that both blocks of retention trials were administered on the same day.) A ten week retention interval was selected to allow completion of the initial data collection phase, that is practice and testing, and to coincide with the summer semester.

Five random sequences were created of the nine scenarios from disk #1, with each scenario appearing twice per block. Thus, there were 18 engagements in each of the three practice blocks. Each subject was trained using 3 of the sequences, chosen at random. For the transfer test subjects received a subset of either VIGS disk #2 or #3, in alternating order: Odd numbered subjects were tested with exercises from disk #2, even numbered subjects were tested with exercises from disk #3. For the retention test, subjects received a block of exercises selected from VIGS disk #1 and then, after a break, a block of 20 exercises from the same VIGS disk (2 or 3) that they had received during the transfer test.

Our initial design had specified that subjects would practice with scenarios from disk #1, be tested with scenarios from a second disk and then receive scenarios from a third disk for the

retention test. Subjects tested with disk #2 would receive disk #3 scenarios for the retention test. Subjects tested with disk #3 would receive disk #2 for the retention test. The use of different sets of VIGS scenarios across the practice, transfer test, and retention test would reduce the possibility that subjects were memorizing specific aspects of individual scenarios.

Unfortunately, during data collection it became evident that kill rates for several of the scenarios from disks #2 and #3 were much lower than expected. Further investigation revealed potential problems with the VIGS scoring system for some scenarios on disks #2 and #3. The low kill rates seemed to be due to inconsistencies in the way that the VIGS system determined if a shot resulted in a kill or miss. (These inconsistencies are described in Appendix B.) Therefore, we modified the experimental design by adding a block of scenarios from disk #1 to the retention test in addition to those scenarios from either disk #2 or #3 which were used as a second block during retention testing.

A summary of the use of the VIGS disks is presented in Table 1.

Table 1

VIGS Disks Used for Each Trial Block

	BLOCK					
	Practice			Transfer	Retention	
	1	2	3	4	5	6
VIGS DISK (all groups)	1	1	1	2 or 3	1	2 or 3

Procedure

The timeline for the procedure for each subject was:

Time	Activity
00 - 15 minutes	orientation
15 - 20 minutes	practice
20 - 40 minutes	session I
40 - 45 minutes	break
45 - 65 minutes	session II
65 - 70 minutes	break
70 - 90 minutes	session III
90 - 95 minutes	break
95 - 115 minutes	session IV
115 - 120 minutes	debriefing/payment

Subjects participated one at a time. Each subject was administered a human subjects consent form and volunteer agreement, (Appendix C). Included as part of the informed consent form was an overview of the purpose and procedure of the research. Next, the subject completed a background questionnaire (Appendix D).

The experimenter then read instructions to the subject. (Appendix E presents a complete list of instructions.) The instructions described the experimental task and included descriptions of the VIGS controls, the target scenarios, and the target kill zone setting. The task required the subject to manipulate switches and manual controls of a tank gunnery simulator in order to fire at target vehicles. Successful performance of the task required several steps. First, the subject flipped a switch to index the ammunition type specified for the scenario. Next, the subject used manual controls to place aiming crosshairs within the target silhouette. Once the crosshairs were on the target the subject pressed a button to "lase" the target, that is, to determine the range to the target. The subject continued tracking the target for at least 1.5 seconds then pressed another button to fire at the target. Each subject fired one round per engagement. The subject was instructed to observe the impact of each round and then look away from the VIGS sight until the beginning of the next scenario. Following the instruction period, the first block of practice trials began.

A five-minute break was provided after each block. At the beginning of the fourth block (test) the experimenter described the change, if any, in the size of the kill zone. After testing, subjects were paid for their participation and informed of the planned retention test.

Subjects returned after 10 weeks for the retention test. Although most of the 45 subjects had indicated that they would be willing to return, only 14 of the subjects could be contacted and scheduled; four from KZ100% and five each from KZ50% and KZ150%. (The high attrition rate may be attributable to the scheduling of the retention test during the summer semester.)

For the retention test each subject was tested with the original set of disk #1 scenarios. After a five-minute rest each subject was tested with either the disk #2 or disk #3 scenarios.

Engagements during which subjects made a procedural error, such as indexing the wrong ammunition, were excluded from the analyses. Procedural errors prevent the determination of the subject's aiming point at the time of firing because the point of round impact does not correspond to the aiming point.

Results

Table 2 presents group means and standard deviations for the three dependent variables, time to fire, kill percentage, and aiming error, for each block of trials. Group means across trial blocks are plotted for kill percentage, time to fire, and aiming error in Figures 1, 2 and 3 respectively. In the tables and figures, the first block of trials of the retention test is labelled Form 1, the second block is labelled Form 2. These labels were chosen to indicate that the two blocks of retention trials used different sets of scenarios but do not represent different retention intervals.

Table 2

Means/Standard Deviations for Time to Fire (TF), Kill Percentage (K%), and Aiming Error (AE) per Group by Trial Block

Block	Group KZ%	TF M	TF (SD)	K% M	K% (SD)	AE M	AE (SD)
1	50	11.34	(3.03)	45	(18)	1.72	(0.33)
	100	9.84	(2.52)	58	(19)	2.58	(1.25)
	150	9.27	(1.57)	65	(17)	2.93	(1.97)
2	50	10.56	(2.57)	59	(12)	1.35	(0.45)
	100	8.67	(1.96)	72	(19)	1.75	(0.53)
	150	8.07	(1.16)	80	(10)	1.85	(0.74)
3	50	10.40	(2.42)	59	(12)	1.31	(0.26)
	100	8.09	(1.47)	76	(17)	1.52	(0.43)
	150	7.82	(1.26)	85	(10)	1.46	(0.62)
4 (Test)	50	11.57	(2.55)	44	(13)	2.01	(0.41)
	100	10.16	(2.70)	36	(13)	2.33	(0.53)
	150	9.87	(2.69)	36	(14)	2.69	(1.10)
Retention (Form 1)	50	9.28	(2.07)	85	(07)	1.26	(0.31)
	100	8.39	(0.78)	77	(11)	1.60	(0.78)
	150	8.40	(1.59)	80	(09)	1.47	(0.29)
Retention (Form 2)	50	11.32	(3.81)	36	(05)	2.18	(0.66)
	100	9.26	(2.05)	30	(12)	2.38	(0.30)
	150	9.04	(2.48)	31	(15)	2.71	(1.26)
	(N)						
Difference Score[a]	50(4)	.15	(1.99)	18	(15)	-.40	(0.97)
	100(4)	.54	(1.48)	6	(08)	.01	(0.29)
	150(5)	1.08	(1.52)	6	(19)	-.10	(0.77)

[a] Difference score = Test score - Second Retention Block Score

Practice

The group means for kill percentage are shown in Figure 1. For each of the three blocks of practice trials KZ150% had the highest kill percentage followed by KZ100% and then KZ50%. This pattern, as was expected, corresponds to the differential criteria, determined by kill zone setting, employed during the practice blocks.

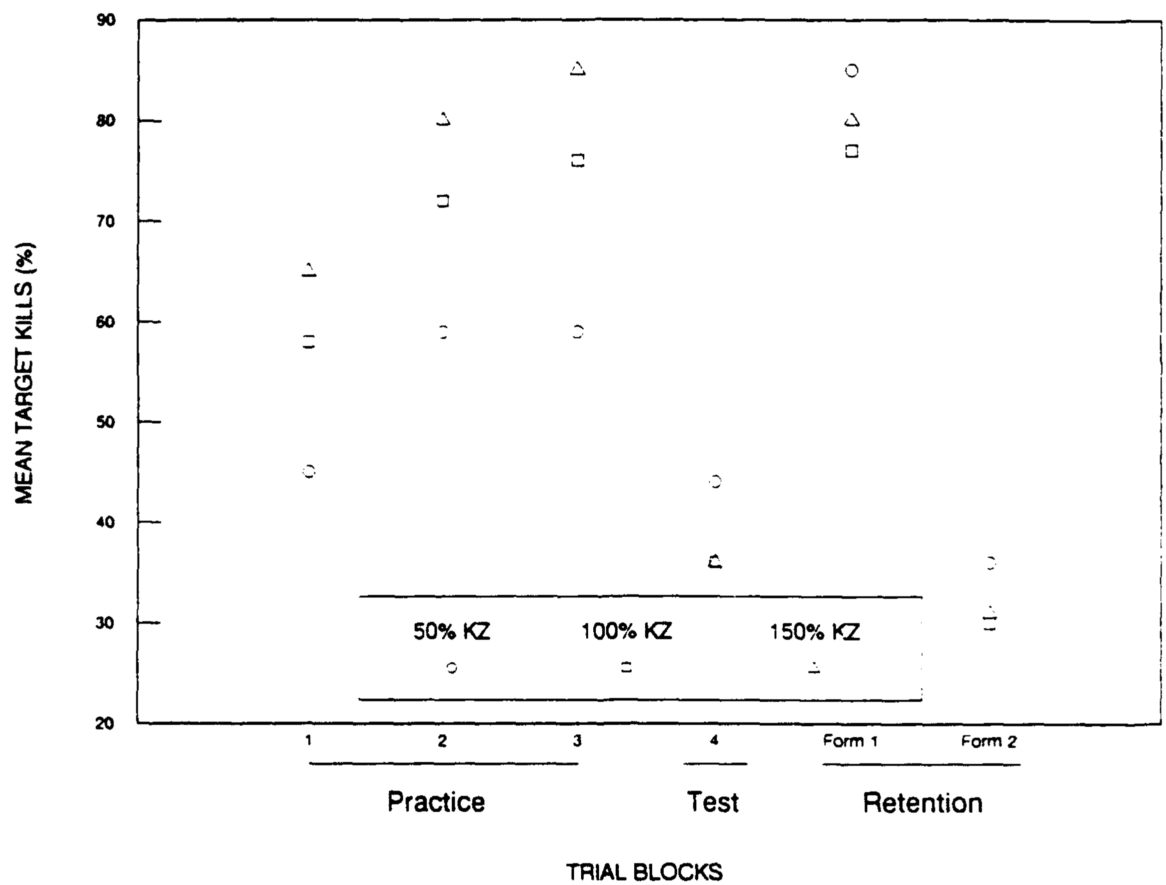

Figure 1. Mean target kills (%) as functions of blocks of practice, transfer, and retention trials for each of three kill zone percentages

The group means for time to fire are shown in Figure 2. KZ50% had the highest (slowest) time to fire across all practice blocks. KZ100% and KZ150% had similar means across all blocks.

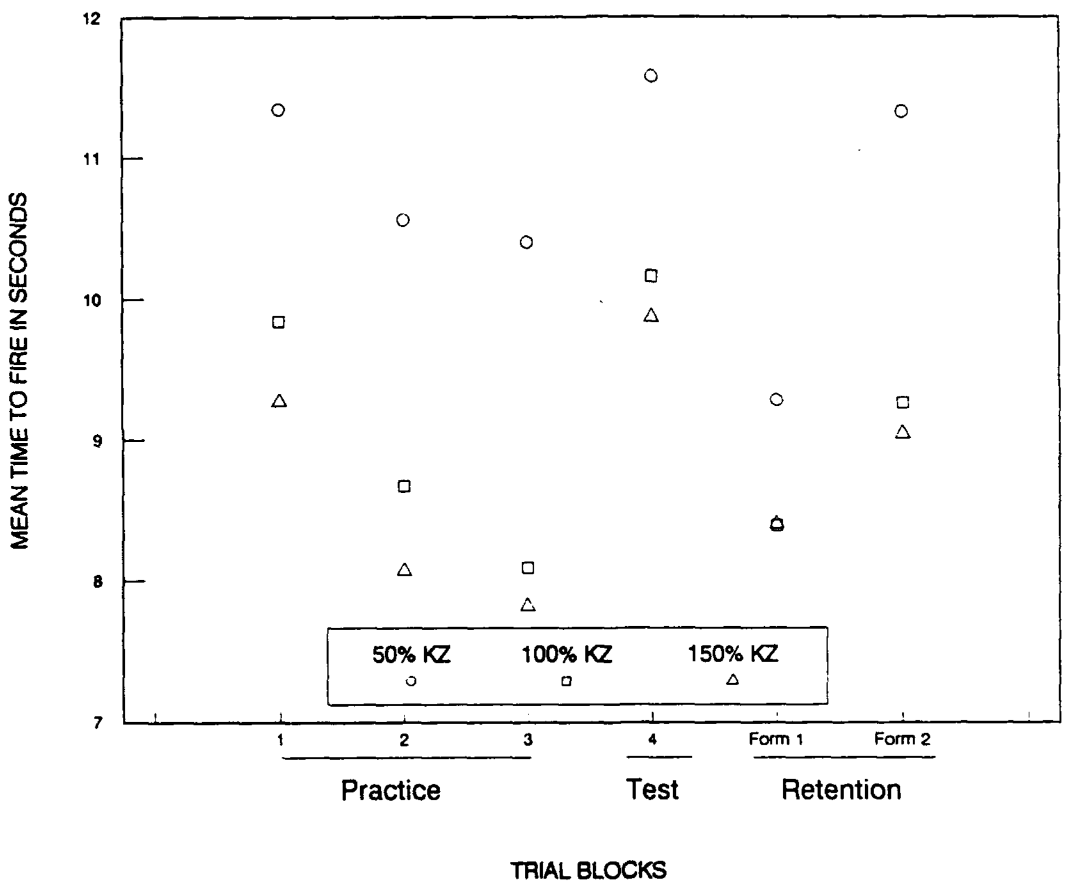

Figure 2. Mean time to fire as functions of blocks of practice, transfer, and retention trials for each of three kill zone percentages

The group means for aiming error are shown in Figure 3. (Aiming error is a measure of absolute distance (pythagorean function of azimuth and elevation deviation) from target center of mass to round impact, measured in milliradians, a measure of visual angle.) KZ50% displayed a consistent superiority (smallest mean error) across all blocks.

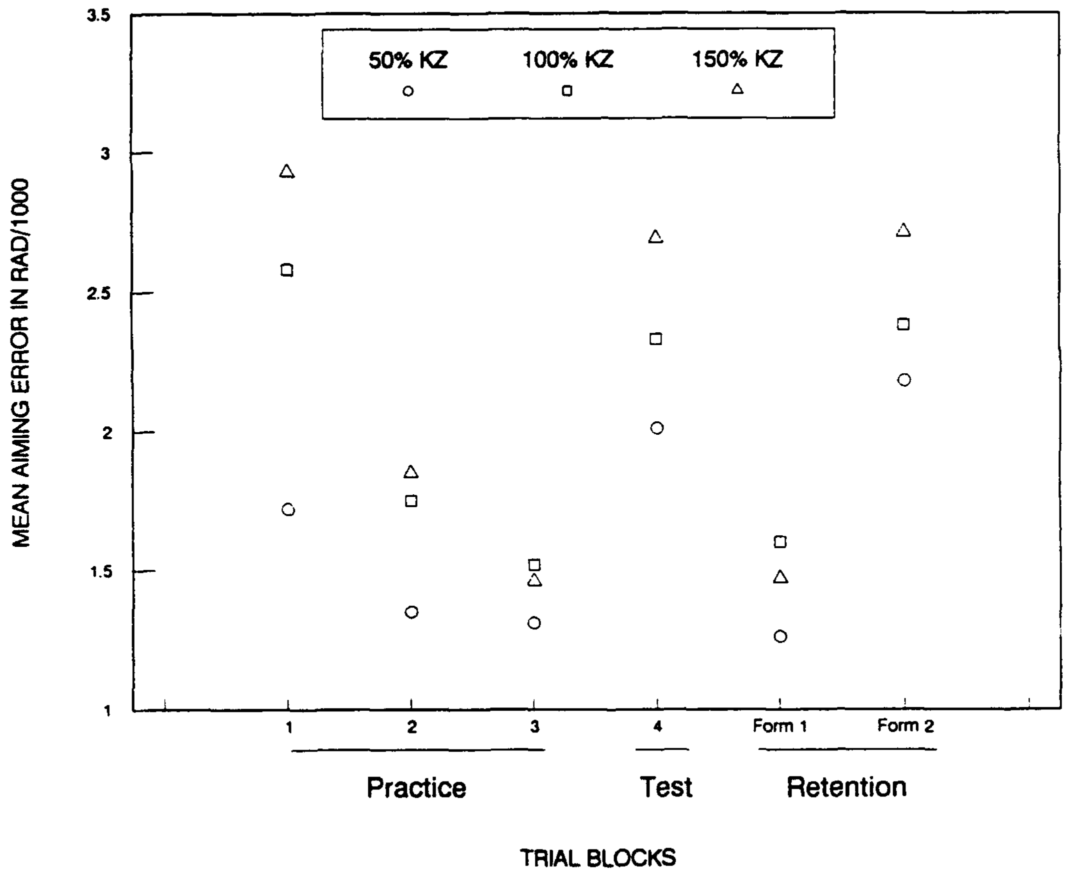

Figure 3. Mean aiming error as functions of blocks of practice, transfer, and retention trials for each of three kill zone percentages

A doubly multivariate analysis of variance (MANOVA) was conducted on practice performance (trial blocks 1-3), with a between-subjects factor of group assignment, a within-subjects factor of trial block, and three dependent variables (kill percentage, time to fire, and aiming error). Wilks' lambda was used to determine statistical significance. (All analyses were conducted using the Statistical Package for the Social Sciences.)

MANOVA results are reported in Table 3 for the doubly multivariate analysis, followed by each singly multivariate analysis. For the practice data, significant main effects were found for group assignment and trial block, indicating that gunnery performance differed as a function of group assignment and as a function of amount of practice. The interaction of group assignment and block was not significant.

Table 3

MANOVA Summary Tables

EFFECT	WILKS'	APP. F	HYP. DF	ERR. DF	SIG.
PRACTICE BLOCKS:					
GRP	.36	8.93	6	80	.000
BLOCK	.27	16.86	6	37	.000
GRP X BLOCK	.68	1.32	12	74	.228
TEST BLOCK:					
GRP	.75	2.11	6	80	.061
RETENTION BLOCK 1:					
GRP	.80	.36	6	18	.895
RETENTION BLOCK 2:					
GRP	.73	.45	6	16	.838

Note. Dependent measures = kill percentage, time to fire, and aiming error.

To further investigate the significant main effects found for practice performance, univariate ANOVAs were run for each of the dependent variables (See Tables 4,5,and 6). The results of each of these analyses paralleled the MANOVA results: group and trial effects were significant with no significant interactions.

Table 4

ANOVA Summary Table for Kill Percentage by Practice Blocks

SOURCE	DF	F	p LEVEL
MAIN EFFECTS:			
GRP	2,42	12.91	.000
BLOCK	2,84	29.66	.000
INTERACTION:			
GRP X BLOCK	4,84	.28	.888

Table 5

ANOVA Summary Table for Time to Fire by Practice Blocks

SOURCE	DF	F	p LEVEL
MAIN EFFECTS:			
GRP	2,42	5.98	.005
BLOCK	2,84	37.94	.000
INTERACTION:			
GRP X BLOCK	4,84	1.11	.356

Table 6

ANOVA Summary Table for Aiming Error by Practice Blocks

SOURCE	DF	F	p LEVEL
MAIN EFFECTS:			
GRP	2,42	4.28	.020
BLOCK	2,84	18.43	.000
INTERACTION:			
GRP X BLOCK	4,84	1.74	.149

To determine significant differences among groups, Duncan multiple range tests were conducted for each of the three dependent variables. For kill percentage, time to fire, and aiming error the means for KZ50% differed significantly ($p<.05$) from the means for KZ100% and KZ150%, which did not differ significantly. The range tests were based on one-way ANOVAs of the variables collapsed across practice trials. All of the ANOVAs were significant ($p<.05$).

Transfer and Retention

Separate MANOVAs, see Table 3, were conducted on the transfer test (trial block 4), and the two blocks of the retention test. Results of these MANOVAs were not significant, although results for the transfer test (block 4) analysis ($F = 2.112$, d.f. = 6, 80) approached significance ($p = .061$). (The small number of subjects participating in retention testing greatly limited the power of the analyses and impeded evaluation of the effects of the experimental treatments on retention.)

Separate ANOVAs were conducted for each of the dependent variables for the test block (Table 7), retention block 1 (Table 8) and retention block 2 (Table 9). None of these analyses were significant, although for aiming error the main effect of group ($F = 3.07$, df = 2,42) during the test block (see Table 7) approached significance with a p level of .057.

Table 7

ANOVAs Summary Table Across Groups for Kill Percentage, Time to Fire, and Aiming Error by Test Block

DEP. VAR.	DF	F	p LEVEL
KILL PERCENTAGE	2,42	1.85	.170
TIME TO FIRE	2,42	1.77	.182
AIMING ERROR	2,42	3.07	.057

Table 8

ANOVAs Summary Table Across Groups for Kill Percentage, Time to Fire, and Aiming Error for Retention Form 1

DEP. VAR.	DF	F	p LEVEL
KILL PERCENTAGE	2,11	.94	.419
TIME TO FIRE	2,11	.47	.635
AIMING Error	2,11	.57	.581

Table 9

ANOVAs Summary Table Across Groups for Kill Percentage, Time to Fire, and Aiming Error for Retention Form 2

DEP. VAR.	DF	F	p LEVEL
KILL PERCENTAGE	2,10	.27	.769
TIME TO FIRE	2,10	.83	.466
AIMING ERROR	2,10	.40	.679

Group means for kill percentage are shown in Figure 1. For the blocks of trials for which all groups encounter the same kill zone setting, that is, the transfer test and the two blocks of retention testing, the mean kill percentage for KZ50% was consistently higher than the means for KZ100% or KZ150%. Group means for time to fire are shown in Figure 2. KZ50% had the highest (slowest) time to fire across blocks. KZ100% and KZ150% had similar means across all blocks. Group means for aiming error are shown in Figure 3. KZ50% consistently had the lowest aiming error across all blocks.

Table 2 presents mean difference scores derived by subtracting each subject's score on the second block of the retention test from the subject's score on the transfer test. KZ50% showed the greatest change in accuracy with the largest losses in both kill percentage and aiming accuracy. All groups showed a slight increase in firing speed.

Difference scores were also calculated for KZ100%, the control group, by subtracting the retention block 1 scores from the last practice block scores. Kill rate declined by 2 percentage points, time to fire was .5 seconds slower, and aiming error increased by .17 milliradians.

A Cronbach's alpha measure of test reliability was calculated for each of the tests, comprised of disk 2 scenarios and disk 3 scenarios, used for the transfer test. For the test made up of disk 2 scenarios alpha was .53. For the test made up of disk 3 scenarios alpha was .56.

Discussion

Practice

During acquisition (practice) trials the kill zone setting manipulation resulted in significant performance differences among groups. The observed differences in kill rate resulted as a direct function of the kill zone size, that is, if the kill zone setting manipulation had produced no change in subject behavior we would still observe differences across groups simply as a function of differences in kill zone size. However, significant differences were also found for the other dependent variables: time to fire and aiming error. The groups did perform differently even though the manipulation of kill zone setting produced no visible change in the target presentation. The group under the reduced kill zone condition had slower firing times and less aiming error than the control group and the expanded kill zone group. The requirement for all subjects to lase within the target silhouette, regardless of kill zone size, probably tended

to mitigate any effect of kill zone size for the expanded kill zone group.

The finding that a speed/accuracy trade-off occurred during the practice trials is consistent with previous research; Fitts and Posner (1967) emphasized that the performance of many skills displays a speed/accuracy trade-off. However, the direction of the trade-off, accuracy emphasized over speed for the reduced kill zone setting, differs from results reported by Abel (1986) which indicated an emphasis on speed over accuracy for a similar task with a reduced kill zone setting. Our procedure limited subjects to one round per engagement which may have resulted in an emphasis on firing accuracy rather than speed of engagement.

Rabbit (1989) noted that for research involving self-paced tasks the experimental instructions usually direct the subjects to be as fast and as accurate as possible. Rabbit pointed out that these instructions leave the subjects to decide what is the appropriate emphasis for speed versus accuracy. For subsequent research an attempt should be made to restrict variation in subject performance to either the speed or accuracy dimension. For example, a relatively brief response time limit could be imposed to reduce response time variation.

<u>Transfer and Retention</u>

For practical training applications the most useful finding would have been that for the transfer test, or the retention test, either or both of the experimental conditions was superior to the control condition. Superior performance would be defined as some improvement in both speed and accuracy, or, an improvement in one with no offsetting decrement in the other. This was not found. The group that practiced with the reduced kill zone displayed greater accuracy, in both kill rate and aiming error, relative to the control group (the difference was statistically nonsignificant), but suffered slower firing times.

Although the experimental hypotheses were not supported, the results of this experiment have implications for the conduct of subsequent research. These implications are:

1. The manner in which we attempted to use the VIGS tank gunnery training device as a research device was not appropriate. Some of the characteristics that probably increase the effectiveness of VIGS as a training device decrease the effectiveness of VIGS as a research device. For example, the VIGS scenarios vary greatly in difficulty. Some of the scenarios provide relatively easy engagement of slow targets moving at a constant rate. For other scenarios, however, the targets unpredictably change speed and direction. Although these scenarios provide challenging engagements for even experienced gunners, as research materials the scenarios do not allow the

identification, measurement, or control of the dimensions of scenario difficulty.

2. Unexpectedly low kill rates were obtained with some of the VIGS scenarios. The collection and graphic display of azimuth and elevation aiming error allowed for a more meaningful interpretation of performance than could have been obtained from only kill rate measurement. In addition, analysis of the direction of error--left versus right for azimuth, high versus low for elevation--seems preferable to sacrificing this information by computing the geometric aim deviation without regard to the direction of deviation. Analysis of shot patterns for individual scenarios may reveal systematic deviation, in azimuth or elevation, from target center of mass. This deviation may be indicative of problems with the training scenario or systematic problems in trainee performance.

3. An experimental procedure that limits subjects to one round per engagement places a greater emphasis on accuracy rather than speed of engagement. Limiting subjects to one round per engagement avoids cross subject variation in the number of rounds fired during acquisition and testing. However, this limitation imposes task demand characteristics that differ from standard use of gunnery simulators and live fire conditions for which multiple firing is allowed and sometimes required.

Finally, this research has implications for tank gunnery training. Training approaches that encourage or require trainees to engage targets with a small kill zone may tend to produce slower firing times. Training managers should weigh the benefits of increased accuracy against the loss in speed of firing.

References

Abel, M.H. (1986). Performance of soldiers on the Battlesight Gunnery Video Game. (Technical Report 710). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A178 446)

Adams, J.A. (1987). Historical review and appraisal of research on the learning, retention, and transfer of human motor skills. Psychological Bulletin, 101(1), 41-74.

Day, R.H. (1954). The effect of size of target on accuracy of aim. American Journal of Psychology, 67, 659-667.

Day, R.H. (1956). Relative task difficulty and transfer of training in skilled performance. Psychological Bulletin, 53(2), 160-168.

Ecklund, J.A. (1975). A comparison of the effect of variation in task difficulty in the transfer of basketball shooting accuracy among college, senior high, and junior high females. (Doctoral dissertation). Eugene: Microform Publications, College of Health, Physical Education and Recreation, University of Oregon, 1977.

Fitts, P.M., & Posner, M.I. (1967). Human performance. Belmont, CA: Brooks/Cole.

Holding, D.H. (1962). Transfer between difficult and easy tasks. British Journal of Psychology, 53(4), 397-407.

Holding, D.H. (1965). Principles of training. London: Pergamon Press.

Hughes, R.G. (1979). Advanced training features: Bridging the gap between in-flight and simulator-based models of flying training. (AFHRL Tech. Rep. 78-96). Brooks AFB, TX: Air Force Human Resources Laboratory.

Igbanugo, V.C. (1972). The effect of task difficulty on transfer of accuracy. Unpublished master's thesis. Smith College, New Hampton, Maine.

Kelley, C.R. (1969). What is adaptive training? Human Factors, 11, 547-556.

Lintern, G.L. (1991). Instructional strategies. In J. E. Morrison (Ed.), Training for performance: Principles of applied human learning (pp. 167-191). Chichester: John Wiley & Sons.

Mace, C.A. (1931). The influence of indirect incentives upon the accuracy of skilled movements. British Journal of Psychology. 22, 101-114.

Mane, A.M., Adams, J.A., & Donchin, E. (1989). Adaptive and part-whole training in the acquisition of a complex perceptual-motor skill. Acta Psychologica, 71, 179-196.

M1/M1A1, Tank Videodisc Gunnery Simulator (VIGS), Device 17-142: Instructor's utilization handbook for simulation equipment. (1988). ECC International Corp. P.O. Box 598022. Orlando, FL 32859

Rabbit, P.M. (1989). Sequential reactions. In D.H. Holding (Ed.), Human skills (pp. 171-195). Chichester: John Wiley & Sons.

Scannell, R.J. (1964). Transfer of accuracy training when difficulty is controlled by varying target size. Unpublished doctor's dissertation. Department of Physical Education. Pennsylvania State University, University Park.

Schmidt, R.A. & Bjork, R.A. (in preparation). New conceptualizations of practice: Common principles in three research paradigms suggest important new concepts for practice. (Research Note). Alexandria, VA: US Army Research Institute for the Behavioral and Social Sciences.

Sticha, P.J., Singer, M.J., Blacksten, H.R., Morrison, J.E., Cross, K.D. (1990). Research and methods for simulation design: State of the art. (ARI Technical Report 914). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A230 076)

Wightman, D.C. & Lintern, G. (1985). Part-task training for tracking and control. Human Factors, 27(3), 267-283.

Williges, R.C., & Baron, M.L. (1973). Transfer assessment using a between-subjects central-composite design. Human Factors, 15(4), 311-319.

Witmer, B.G. (1988). Device-based gunnery training and transfer between the Videodisk Gunnery Simulator (VIGS) and the Unit Conduct of Fire Trainer (UCOFT). (ARI Technical Report 794). Alexandria, VA: U.S. Army Research Institute for the Behavioral and Social Sciences. (AD A197 769)

APPENDIX A

DESCRIPTION OF VIGS

VIGS: The M1 Videodisc Gunnery Simulator (VIGS) is a tabletop part-task trainer for M1 or M1A1 tank gunnery. The VIGS trainer utilizes computer generated imagery (CGI) to present engagement scenarios to the trainee. The scenarios depict stationary and moving targets and realistic terrain. The CGI scenarios, and a series of target identification slides, are stored on videodisk. The scenarios are of approximately 45 to 60 seconds duration. Through the use of synthesized speech, a simulated "tank commander" issues standard fire commands, specifying the target type, required ammunition, and fire directives. At the end of the engagement, trainees can be provided detailed performance measures via a screen display and by an optional on-line printer.

The VIGS performance measures are presented on an embedded cathode ray tube, and are separated into 3 screens. The first screen is titled the "Scoring Screen", and includes the following information: Trainee Point Score, calculated according to a formula which combines elements of speed, accuracy and procedural performance; Possible Point Score, the total point score attainable; the length of the scenario in seconds; the Total Session Score, reflecting a cumulative record of trainee performance; Session Performance, a cumulative percentage score based on session score; Rating, which may be Distinguished, Superior, Qualified, or Unqualified, depending upon the trainee's Session Performance score; Total Rounds Fired and Remaining for both main gun and COAX ammunition; COAX Target Coverage; and detailed information regarding each round fired. This information includes point-of-impact azimuth and elevation displacement in milliradians from target center of mass.

The second screen is entitled the "Critique Screen" and includes verbal descriptive phrases informing trainees of specific inadequate performance. Time taken to kill the target is also included on this screen.

The third screen is the Summary Screen, and repeats the azimuth and elevation displacement of each round given on the Scoring Screen. Also, time taken to fire the round is shown, as is the round's effectiveness (hit or miss). Because of the complexity of the information displayed on the VIGS screens a shield was placed at the side of the cathode ray tube so that the subject could not view, and be distracted by, the display during the experiment. The shield did not block the view of the experimenter.

For this research, the VIGS was modified to include a printer, used to create hard copies of performance reports (information dumps from the VIGS data screens) and a keyboard, used to initiate the printouts and to alter some of VIGS' parameters.

Four different videodisks of scenarios are available for the M1 VIGS. Each VIGS scenario depicts a scene as viewed through the gunner's sight of an M1 tank. Each scene contains terrain, such as hills or flat stretches of sand. Most scenes also contain vegetation, such as grass and trees, and cultural objects, such as houses. CGI targets are superimposed upon the terrain representation. Target types are: tanks, helicopters, BMPs (Warsaw Pact infantry fighting vehicles), trucks, and troops. Some scenarios present single targets, some present two targets. Stationary and moving targets are presented and some scenarios represent movement by the firing vehicle.

APPENDIX B

DISCUSSION OF PROBLEMS WITH VIGS SCENARIOS

Target kill rates for some of the scenarios from VIGS disks 2 and 3 were much lower than target kill rates for scenarios from disk 1. This appendix describes our efforts to determine the basis of the lower kill rates, the identification of possible technical problems with some of the scenarios, and the training implications of the problems.

Many of the subjects complained during the transfer test that on several of the test scenarios their shots were incorrectly being scored as misses. These subjects, who had developed confidence during the three blocks of practice trials, claimed that they had correctly engaged targets but the VIGS system had incorrectly computed misses instead of kills. For the two worst cases, mission 22 from disk 2 and mission 6 from disk 3, less than 5 percent of the rounds fired were recorded as kills.

For each of the VIGS exercises used in this experiment graphs of subjects' shot patterns were generated. The graphs depict the dispersion, in milliradians, of rounds with the origin of the graph corresponding to the center of the target. (The numbers and letters indicate the number of rounds falling at a single plot point. Because two digit numbers can not be printed at a single point letters are used: A=10, B= 11, ..., Z = 35, * = 36 or more). Many of these patterns show rounds centered around the graph origin, as we expected. These patterns indicate that rounds consistently hit near the target center with the dispersal pattern centered on the origin. An example of this type of result is the shot pattern for scenario 5 (Mission 5) from disk 1. This graph (Figure 4) shows shots evenly clustered about the origin.

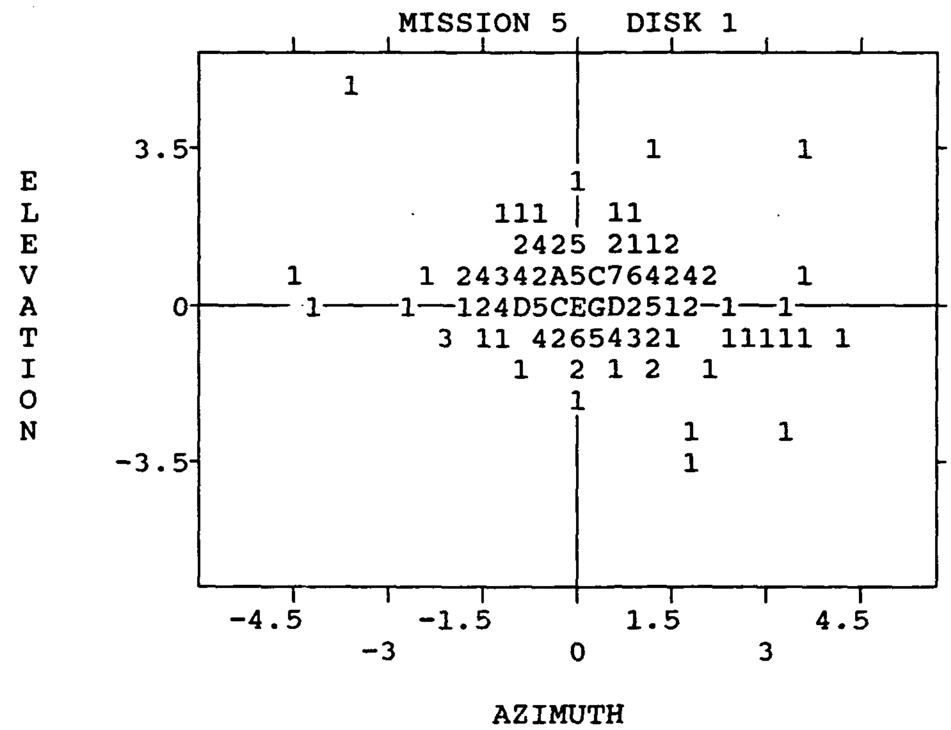

Figure 4. Shot pattern for VIGS Mission 5 from Disk 1

Most of the shot patterns for disk 1 scenarios were evenly distributed about the center of the target. In contrast, many of the patterns for scenarios from disks 2 and 3 were not centered around the graph origin; the majority of the rounds fell above the target center. An example of these unexpected shot patterns is shown in Figure 5.

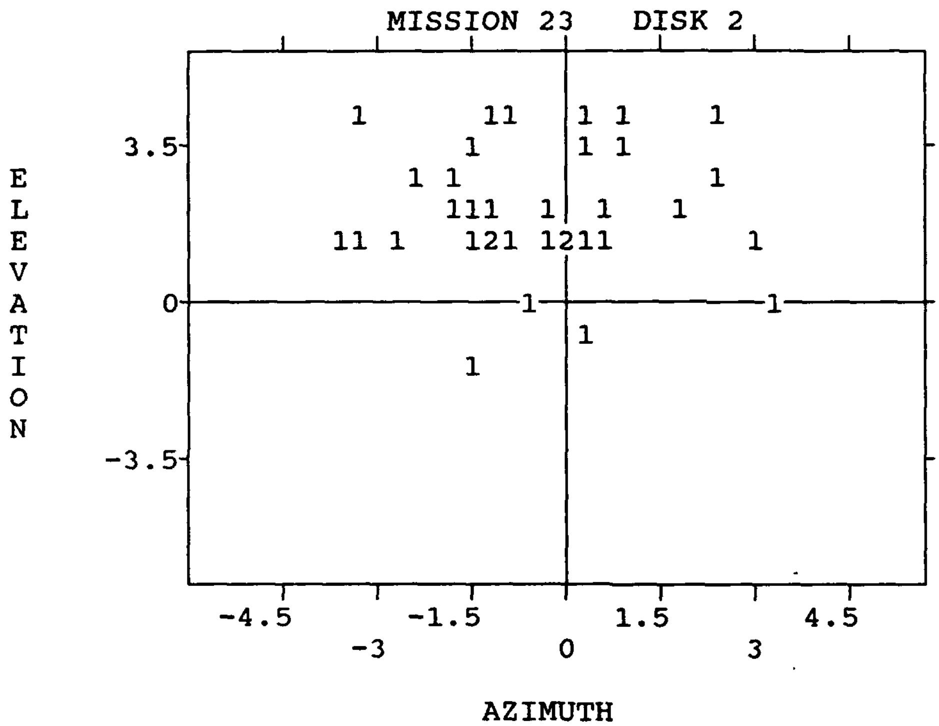

Figure 5. Shot pattern for VIGS Mission 23 from Disk 2

The instructions to the subjects described only the basic procedures required to track and engage targets. The instructions did not cover complex aspects of tank gunnery, such as multiple returns from the laser range finder, and tracking procedures for engagements in which target movement is not limited to a horizontal plane. Successful engagement of some of the targets from disks 2 and 3 may require the use of gunnery procedures beyond the scope of the instructions and practice provided to subjects in this experiment. However, the low kill rates recorded for some of the scenarios from disks 2 and 3 may be the result of technical problems with those scenarios.

Informal investigation of the "problem" scenarios indicated that there may be a discrepancy between the screen representation of the location of the target, where the target appears to be, and the system representation, the coding of target location used to determine if a shot is a hit or miss. Discrepancies were determined by repeatedly lasing within and slightly outside of the target silhouettes. For example, for several of the scenarios, lasing on the upper third of the target produces a range figure which is approximately 400 to 600 meters more distant than the figure which results from lasing on the lower two thirds of the target. The discrepancy in range determination produces a corresponding discrepancy in firing accuracy. When a trainee fires after lasing on the upper portion of the target, the round lands beyond the target; however, when the trainee fires after lasing on the bottom portion of the target, or just below the target, the round will hit the target.

Representatives of the VIGS manufacturer, the Education Computers Corporation, were consulted to try to resolve our questions concerning the VIGS scenarios. The representatives pointed out that VIGS was developed to serve as a low-cost training device. They acknowledged that for a few of the scenarios there could be minor discrepancies between the visual representation of target location and the internal system representation of target location. Discrepancies could also exist between the representations of the aiming reticle. They expressed the view that these discrepancies did not compromise the training effectiveness of VIGS.

Experienced tank gunnery instructors could be used to test the scenarios from disks 2 and 3 to determine if technical problems exist and to provide some indication of the problems' potential effects on training effectiveness. An acceptable percentage of first round kills would indicate that the VIGS scenarios functioned properly and that the low rates we observed were the result of inadequate instructions or practice given to our subjects. However, if for some of the scenarios very low kill rates are obtained even with experienced gunners then this information should be made available to the managers of VIGS training.

Training managers may wish to omit the problem scenarios during VIGS training. It would seem inappropriate to use scenarios for which proper engagements techniques sometime lead to unexplained misses and improper techniques, such as aiming below the target, result in kills. On the other hand, the managers may be able to incorporate the problem scenarios into the training plan, for example, by using them to explicitly demonstrate an aspect of live fire; sometimes the gunner correctly performs all procedures, obtains a correct sight picture, and yet a round still misses.

APPENDIX C (SIDE 1)

HUMAN SUBJECTS CONSENT FORM AND VOLUNTEER AGREEMENT

I, ____, having full capacity to consent, do hereby volunteer to participate in research entitled Application of Learning Principles to Device-based Training under supervision of the US Army Research Institute. The implications of my voluntary participation and the nature, duration, and purpose of the research, and the method and means by which it is to be conducted are contained on the reverse side of this form. I have been given an opportunity to read and keep a copy of this Agreement and to ask questions concerning this research. Any such questions have been answered to my full and complete satisfaction. Should any further questions arise, I will be able to contact Don Lampton at 380-4368. I understand that I may at any time during this research revoke my consent and withdraw from the test without prejudice, but I will not be paid unless I complete 2 full hours.

____
(Signature, Date)

I was present during the explanations referred to above as well as the volunteer's opportunity for questions and hereby witness his signature.

______________________________ ______________________
(Witness) (Date)

APPENDIX C (Side 2)

HUMAN SUBJECTS CONSENT FORM AND VOLUNTEER AGREEMENT

For many educational, industrial and military applications computer-based training simulations provide an inexpensive and safe complement to training with operational systems and equipment. This experiment is part of a project to develop better methods of training with simulators. The purpose of this experiment is to evaluate training effectiveness as a function of the relation between the level of difficulty of early stages of training and the level of difficulty of later stages of training.

You will be asked to practice an aiming task using a computer-based training simulator which was developed to train tank gunnery. You will aim and fire at a series of targets. After each shot you will receive an indication of whether you hit or missed. The task involves setting a series of switches and using manual controls to track a target. (The device display and the required task are somewhat similar to the displays and tasks used for many video games.) After an initial practice period you will complete 4 sessions of tracking tasks. Each session will consist of approximately 18 targets. The degree of aiming accuracy required to produce a hit may vary across sessions. Required accuracy will be explained at the beginning of each session.

Schedule:

Time	Activity
00 - 15 minutes	orientation
15 - 20 minutes	practice
20 - 40 minutes	session I
40 - 45 minutes	break
45 - 65 minutes	session II
65 - 70 minutes	break
70 - 90 minutes	session III
90 - 95 minutes	break
95 - 115 minutes	session IV
115 - 120 minutes	debriefing/payment

The risks involved are those associated with viewing standard video display screens.

You are free to terminate participation in this experiment at any time without bias. However, you will not be paid unless you complete the 2 hour session.

Do you have any questions?

APPENDIX D

SUBJECT BACKGROUND INFORMATION

The purpose of this questionnaire is to collect background information on participants in the ARI tank gunnery training research. This information will be used strictly for research purposes only. Please complete each item to the best of your ability. Write "N/A" for each item you cannot answer.

1. Name:____
   Last First M.I.

2. Social Security Number:______-_____-_______

3. Date of Birth:_____/____/_____

4. Present grade classification (Junior, Senior, etc.)______________

5. How often do you play video games (circle one)?

   A. less than once per week
   B. once per week
   C. 2-4 times a week
   D. greater than 4 times/week

6. Have you ever been diagnosed as color blind/deficient?______

APPENDIX E

INSTRUCTIONS TO SUBJECTS

Hello. My name is ____________________ with the Army Research Institute. Today you will train for approximately 2 hours on the VIGS tank gunnery trainer.

Please have a seat in front of the trainer. Look at the two connected handles. These handles move the aiming crosshairs up, down, and side to side. To move the crosshairs side to side, turn the handles like a steering wheel. To move them up or down, twist the handles accordingly. (demonstrate)

You will also notice two sets of buttons. The first set of buttons, located near the top and inner portions of the handles, controls the laser rangefinder. This gives you a "range lock" on the target, and computes the target's range, which is then shown on the screen. The second set of buttons, located near your index fingers, are the fire buttons. Finally, in order for any buttons or movements to work, **THE PALM LEVERS ON THE FRONT OF THE HANDLES MUST BE ENGAGED!!!**

When engaging a target, the sequence of activities is:

1. **Squeeze the palm levers and hold them down throughout the engagement.**

2. Manipulate the handles to bring the crosshairs to the center of the target.

3. When the crosshairs are on the target press the lase buttons. For moving targets you must track the target for at least one and a half seconds before you fire.

4. After the tank commander gives the **"FIRE"** command, press the fire button, keeping the crosshairs on the center of the target.

5. Continue tracking the target until the round lands. Look away from the sight after the round lands.

YOU MUST FIRE ONLY ONE ROUND AT EACH TARGET PRESENTED!

Look at the panel in front of you. Before an engagement begins, I will indicate what type of engagement to expect. There are two possibilities:

1. **"Normal Engagement".** In this case, the shutter switch needs to be set on **"clear"** and the thermal mode switch must be on **"standby"** (Demonstrate).

2. **"Thermal Engagement".** In this case, the shutter switch must be turned clockwise to **"SHUTTR".** Also, the thermal mode switch must be set to **"ON"** (Demonstrate).

After proper setting of the shutter and thermal mode switches, the engagement will begin. An automated tank commander will move you near the target, while telling you the type of ammunition to use (i.e., **"GUNNER, SABOT"** or **"GUNNER, HEAT"**).

After hearing this, you must manipulate the ammunition selection switch accordingly.

At this point, you should place the crosshairs on the target, press the lase button, and fire, continuously tracking the target until the round falls.

During the first practice sessions, the required accuracy for target destruction will be either smaller, larger, or the same as that for the last session (the test session).

<<At this point, read appropriate group instructions>>

Instructions for subjects in 150% group

For the first three blocks of trials the target kill zone is set so that a shot that lands slightly outside the target is still scored as a hit. However, the crosshairs must be within the target when you lase. For the last block the kill zone will be set so that you must hit within the target to be credited with a hit.

Your goal is to hit targets as rapidly as possible.

Instructions for subjects in 100% group

For the first three blocks of trials and the test block the target kill zone is set so that a shot that lands anywhere within the target is scored as a hit. The crosshairs must be within the target when you lase.

Your goal is to hit targets as rapidly as possible.

Instructions for subjects in 50% group

For the first three blocks of trials the target kill zone is set so that in order for a shot to be scored as a hit the shot must land near the center of the target. The kill zone is actually about 1/2 of the size of the target that you see. However, the crosshairs can be anywhere within the target when you lase. For the last block the kill zone will be set so that a shot landing anywhere within the target will be scored as a hit.

Your goal is to hit targets as rapidly as possible.

You should engage the targets as quickly and as accurately as possible at all times.

Are there any questions regarding these instructions?

TO SUMMARIZE:

1. Manipulate the Shutter and Thermal Mode switches according to the experimenter's instructions (Normal or Thermal).

2. Upon hearing the tank commander, set the Ammunition Select switch.

3. Squeeze palm levers and hold them down.

4. Move the crosshairs onto the center of the target.

5. Press the lase button, continue tracking.

6. After the Tank Commander says "Fire" press the fire button.
7. Observe where the round hits, then look away from the screen.